SPECIFICATION

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CLOSE PACKING LED ASSEMBLY WITH VERSATILE INTERCONNECT ARCHITECTURE

Background of Invention

[0001] The invention relates to the electronic and optoelectronic arts. It is especially applicable to the packaging of light emitting diodes (LED's), and will be described with particular reference thereto. However, the invention will also find application in the packaging other electronic and optoelectronic devices, such as photodetectors, signal receivers, vertical cavity surface emitting lasers (VCSEL's), photovoltaic devices, and the like.

[0002] Light emitting diodes (LED's) find application in fiber optical communications, lighting applications, display applications, and other applications where a compact, low voltage, rugged, and high efficiency light source is advantageous. In many LED applications, a plurality of LED's are advantageously arranged into an array or other pre-determined arrangement comprising similar or dissimilar LED types. In lighting or display applications, LED's emitting in the red, green, and blue regions are preferably closely packed to form a color "pixel" that blends the three colors. In this manner white light can be generated. Alternatively, by selectively varying the optical output intensity of the three colored LED's, a selected color can be generated. An array of such "pixels" can form a color display or an illuminating surface emitting white light, among other applications.

[0003] The prior art includes fabrication of LED arrays on-chip. In this approach, semiconductor layers comprising the LED's are generated on a substrate, usually a semiconductor substrate, and individual LED's of the array are isolated by etching mesas in the LED layers. This approach is limited in application. The LED's are typically

required to be all of one type. The choice of substrate is limited to those compatible with the semiconductor layer generation method. Many commercial LED's are formed from III-V compound semiconductor layers, and the substrates which are used for the growth of such layers, typically including GaAs and InP wafers, sapphire substrates, and the like, are often expensive, fragile, and of limited lateral area.

[0004] A much more flexible approach is to fabricate discrete LED's using any convenient method, and then to bond the discrete LED's to a host substrate to form the LED arrangement thereon. In this manner dissimilar LED's, such as red, green, and blue LED's comprised of different material layers, can be advantageously combined. The choice of substrate is greatly expanded. However, the individual LED's are electrically isolated, so that intricate wire bonding or other electrical interconnecting methods are typically applied to complete the array. Additionally, a different host substrate shape and electrical interconnect pattern is needed for each distinct LED arrangement, which limits the standardization of parts and complicates array manufacturing.

[0005] The present invention contemplates an improved modular mounting assembly for forming arrays of LED's and other components.

Summary of Invention

[0006] In accordance with one embodiment of the present invention, a mounting structure for assembling a plurality of optoelectronic components is disclosed. A first substrate has at least one first optoelectronic component arranged thereon. The first substrate is in the shape of a rhombus and has an edge connector disposed on an edge thereof. A second substrate has at least one second optoelectronic component arranged thereon. The second substrate is in the shape of a rhombus and has an edge connector disposed on an edge thereof which operatively connects with the edge connector of the first substrate to form an arrangement of the at least one first optoelectronic component and the at least one second optoelectronic component.

[0007] In accordance with another aspect of the present invention, at least one of the first substrate and the second substrate has a rhombus shape that corresponds to a primitive unit cell of a hexagon.

[0008] In accordance with another aspect of the present invention, an interconnecting

element connects with the edge connector of the first substrate and with the edge connector of the second substrate to connect the edge connector of the first substrate with the edge connector of the second element.

[0009] In accordance with another aspect of the present invention, the first substrate includes an electrical connection between the at least one first component and the edge connector of the first substrate. The second substrate includes an electrical connection between the at least one second component and the edge connector of the second substrate. The interconnecting element electrically connects the edge connector of the first substrate with the edge connector of the second substrate to form an electrical arrangement of the at least one first component and the at least one second component.

[0010] In accordance with another aspect of the present invention, the first substrate includes a thermally conductive layer, and a printed circuit board into which the edge connector is formed. The printed circuit board includes an electrical path connecting the at least one first optoelectronic component with the edge connector.

[0011] In accordance with another aspect of the present invention, the at least one first optoelectronic component includes at least one light emitting diode (LED). The first substrate includes a lens in operative communication with the at least one LED.

[0012] In accordance with another aspect of the present invention, the at least one first optoelectronic component includes a plurality of light emitting diodes (LED's) disposed on the substrate. The printed circuit board includes an electrical path that electrically interconnects the LED's disposed on the substrate.

[0013] In accordance with another aspect of the present invention, the thermally conductive layer has depressions in which the LED's are arranged, and the printed circuit board has holes arranged to allow the LED light emission to pass through.

[0014] In accordance with another aspect of the present invention, a third substrate has at least one third component arranged thereon. The third substrate is in the shape of a rhombus and has a first edge connector disposed on an edge thereof which operatively connects with a second edge connector of the first substrate. The third substrate also has a second edge connector disposed on an edge thereof which

operatively connects with a second edge connector of the second substrate. The first, second, and third rhombus-shaped substrates are arranged to form a hexagonally shaped mounting structure.

[0015] In accordance with another aspect of the present invention, at least one terminating element completes an electrical circuit.

[0016] In accordance with another aspect of the present invention, at least one terminating element supplies electrical power to the mounting structure.

[0017] In accordance with another embodiment of the present invention, a modular mounting assembly for connecting a plurality of light emitting diodes (LED's) in a selectable electrical and spatial arrangement is disclosed. A plurality of substrates are provided. Each substrate has at least one LED fixedly arranged thereon, and a plurality of connectors arranged thereon that are in electrical communication with the at least one LED. The plurality of substrates are arranged in a spatial arrangement having selected pairs of connectors in electrical communication with each other providing an electrical arrangement between the plurality of LED's.

[0018] In accordance with another aspect of the present invention, an interconnecting element electrically and structurally interconnects selected substrates through pairs of connectors. For example, an interconnecting element cooperates with the selected substrates to form one of a series LED electrical interconnection and a parallel LED electrical interconnection.

[0019] In accordance with another aspect of the present invention, at least one of the plurality of substrates has a rhombic shape.

[0020] In accordance with yet another embodiment of the present invention, an extensible LED structure is disclosed. An LED is supported by a rhomboidal shaped substrate. At least one electrical socket is disposed on the rhomboidal shaped substrate and shaped to receive an electrical plug. The electrical socket provides electrical communication to the LED.

[0021]

In accordance with another aspect of the present invention, a discrete plug mechanically connects the electrical socket to an electrical socket disposed on a

second substrate.

[0022] In accordance with another aspect of the present invention, a plug is integral with the substrate. The plug is mechanically connectable to an electrical socket disposed on a second substrate.

[0023] In accordance with another aspect of the present invention, the plug comprises electrical paths and when the plug is seated in the socket, the electrical paths place the LED in a predetermined electrical relationship with an LED on the second substrate.

[0024] The advantages and benefits of the present invention will become apparent to those of ordinary skill in the art upon reading and understanding the following detailed description.

Brief Description of Drawings

[0025] The invention may take form in various components and arrangements of components, and in various steps and arrangements of steps. The drawings are only for purposes of illustrating a preferred embodiment and are not to be construed as limiting the invention.

[0026] FIGURE *1* shows an exemplary array of twelve rhombic substrates forming a hexagonal array of twenty-four components.

[0027] FIGURE *2* shows the geometry of an exemplary rhombic substrate.

[0028] FIGURE *3* shows a first embodiment of the invention, having two LED components connected electrically in series on a rhombic substrate.

[0029] FIGURE *4* shows a sectional view of the embodiment of FIGURE *3* taken along the Section S-S.

[0030] FIGURE *5* shows an electrical schematic of the substrate of FIGURE *3*.

[0031] FIGURE *6* shows an exemplary interconnecting element that is compatible with the substrate of FIGURES *3* and *5*.

[0032] FIGURE *7* shows an exploded view of an exemplary interconnection of three

rhombic substrates corresponding to the embodiment of FIGURES *3* and *5*.

[0033] FIGURE *8A* shows an electrical schematic of a series connection of two substrates corresponding to the substrate embodiment of FIGURES *3* and *5*.

[0034] FIGURE *8B* shows an exemplary interconnecting element that implements the series interconnection shown in FIGURE *8A*.

[0035] FIGURE *9A* shows an electrical schematic of a parallel connection of two substrates corresponding to the substrate embodiment of FIGURES *3* and *5*.

[0036] FIGURE *9B* shows an exemplary interconnecting element that implements the parallel interconnection shown in FIGURE *8A*.

[0037] FIGURE *10A* shows an electrical schematic of a terminating element that connects the cathode of the last substrate according to the substrate embodiment of FIGURES *3* and *5* to circuit ground.

[0038] FIGURE *10B* shows an exemplary interconnecting element that implements the circuit termination shown in FIGURE *10A*.

[0039] FIGURE *11A* shows an electrical schematic of a terminating element that connects a substrate of the type shown in FIGURES *3* and *5* to a voltage source.

[0040] FIGURE *11B* shows an exemplary interconnecting element that implements the voltage connection shown in FIGURE *11A*.

[0041] FIGURE *12* shows an exemplary series interconnection of three substrates of the type shown in FIGURES *3* and *5* using appropriate interconnecting and terminating elements.

[0042] FIGURE *13* shows a second embodiment of the invention, having two sets of red, green, and blue LED components that provides independent electrical access to the three colors.

[0043] FIGURE *14* shows an electrical schematic of the substrate of FIGURE *13*.

[0044] FIGURE *15* shows a third embodiment of the invention that includes a connector appropriate for connection to a connecting cable.

[0045] FIGURE *16* shows an exemplary arrangement of several substrates of the type shown in FIGURE *15* on an interconnecting cable.

Detailed Description

[0046] With reference to FIGURES *1* and *2*, a modular mounting assembly *10* is described. A plurality of substrates *12* each have one or more components *14* arranged thereon. In the illustrated embodiment of FIGURE *1*, each substrate *12* has two LED components *14* arranged thereon. The plurality of substrates *12* are arranged in a selected manner to form the mounting assembly *10* that arranges the components *14* in a selected arrangement, such as the hexagonal arrangement of FIGURE *1* comprised of twelve substrates *12* and twenty four LED components *14*.

[0047] In one embodiment shown in FIGURES *1* and *2*, each substrate *12* has the shape of a rhombus, i.e. a parallelogram having four sides of essentially equal length L, with oppositely oriented angles equal. Thus, a rhombus can be specified by two angular parameters α and β, along with the side length L, as shown in FIGURE *2*. In the illustrated embodiment of FIGURE *1*, the angles α and β are 60 ° and 120 °, respectively, so that each rhombic substrate *12* corresponds to a primitive unit cell of a hexagon, thus enabling particularly close packing of the components *14* such as in the assembly *10* shown in FIGURE *1*. Hexagonal symmetry is particularly advantageous because hexagons can be arranged to form densely packed two-dimensional arrays. Hexagonal symmetry also can be used to create three-dimensional structures such as spheres or geodesic-type domes.

[0048] In another embodiment (not shown), $\alpha = \beta = 90°$ so that a square unit cell substrate results. It will be appreciated that the rhombic shape provides a high degree of symmetry that enables arrangement of a plurality of rhombic substrates *12* into a wide range of selected spatial arrangements. Of course, other values for the angles α and β can also be used within the geometrical limitation that $\alpha + \beta = 180°$ for the rhombic geometry shown in FIGURE *2*.

[0049]

With continuing reference to FIGURE *1*, each substrate *12* includes one or more connectors *16* that effectuate interconnection of the substrates *12*. In one embodiment, the connectors *16* also cooperate to effectuate electrical interconnection

of the components *14* across the boundaries of paired substrates *12*.

[0050] With reference now to FIGURES *3* and *4*, the substrate *12* is described. Each substrate *12* has two LED components *14a* and *14b* arranged thereon. The LED's *14a*, *14b* can be similar LED's, e.g. two similar LED components that both emit white light. Alternatively, the LED's *14a*, *14b* can be dissimilar LED components, e.g. LED's of different colors, different intensities, different angular distributions, etc.

[0051] With particular reference now to FIGURE *4*, which shows a sectional view taken along the Section S-S shown in FIGURE *3*, the substrate *12* includes a thermally conductive layer *20*, such as a copper plate. In an exemplary embodiment a copper plate about 0.3 cm thick is used. Each LED component arranged on the substrate *12*, e.g. the exemplary LED *14a* is disposed in a receiving depression *22* of the copper plate *20*. The receiving depression *22* is a conical well with a flat bottom. The mounting of an LED die therein can employ thermally conductive cement, a resin, an epoxy, or the like, as is well known to those of ordinary skill in the art. The thermally conductive layer *20* provides heat sinking for the LED components *14a*, *14b*. However, the LED components *14a*, *14b* are advantageously electrically isolated from the copper plate *20*.

[0052] An insulating layer such as a printed circuit board (PC board) *24* is affixed to the thermally conductive layer *20*. The PC board *24* has one or more openings or holes *26* corresponding to the receiving wells *22* of the copper plate *20*, through which the LED light emission passes during LED operation. The substrate *12* optionally includes additional optical components, such as a transparent cover plate *30* and a lens *32* that is in operative communication with the LED *14a*.

[0053] With continuing reference to FIGURES *3* and *4*, the PC board *24* advantageously facilitates electrical connections to the components. A plurality of PC board traces connect the LED's *14a*, *14b* to the connectors *16* and optionally also connect the LED's *14a*, *14b* to each another. For example, a trace *40* can be used to interconnect the LED's *14a*, *14b* electrically in series. The electrodes (not shown) of the LED components *14* are connected to the PC board traces *40* using wire bonds or other means (not shown) that are well known to those of ordinary skill in the art. In one embodiment, the connectors *16* are formed into the edges of the PC board *24* so that

the traces advantageously directly connect to the electrical conductor members comprising the connectors *16*, and the connectors *16* are readily accessible at the edges of the substrate *12*. In the illustrated exemplary embodiment of FIGURE *3*, there are four connectors *16*, and each connector has five conductor members *1*, *2*, *3*, *4*, and *5*.

[0054] With reference now to FIGURE *5*, an electrical circuit schematic is shown corresponding to the exemplary substrate *12* of FIGURES 3 and 4. In the illustrated exemplary embodiment of FIGURE 5, the LED's *14a*, *14b* are connected in series on the substrate *12*. The anode *44* and the cathode *46* of the series LED combination *14a*, *14b* are accessible at connector conductor members *1* and *5*, respectively. Although only two of the five conductor members are directly connected to the components in the exemplary substrate *12*, it will be appreciated that providing additional conductor members, e.g. unattached members *2*, *3*, and *4* advantageously facilitates adding additional components, such as additional LED's, to the substrate *12* and enhances the modularity of the system. Additionally, at least one conductor member is reserved as a circuit ground. In the exemplary embodiment of FIGURES *3* and *5*, conductor member *4* is reserved as the ground conductor. Of course, it will also be recognized that other conductor designations can be made, and additionally more or fewer than five conductor members can be included on each connector *16*. However, for a given modular mounting assembly some standardization of the number and designations of the conductors is highly advantageous.

[0055] With reference now to FIGURES *6* and *7*, an approach for effectuating the interconnection of pairs of connectors *16* is described. An interconnecting element *50A* of a type "A" operatively connects to a pair of connectors *16* at mating ports *52* and *54* of the interconnecting element *50A*. The interconnecting element *50A* mechanically connects to the two substrates *12* that have the pair of connectors *16* to effectuate structural interconnection between the two substrates *12*. The mechanical connection can be by a frictional fit (not shown) or by fastenings *56* which can be screws, rivets, or the like. The interconnecting element *50A* also has a pre-selected electrical configuration that effectuates a desired electrical arrangement of the components of the connected substrates *12*, such as a series connection arrangement, parallel connection arrangement, or the like. As can be seen in FIGURE

6, the two mating ports *52*, *54* each have five electrical connector members *1'*, *2'*, *3'*, *4'*, *5'* that correspond to and electrically connect with the connector members *1*, *2*, *3*, *4*, *5* of the connectors *16* of the substrates *12*. The pre-selected electrical configuration is determined by the electrical interconnections of the two ports *52*, *54* inside the interconnecting element *50A* (not shown in FIGURE 6). Thus, as shown in FIGURE *7*, two interconnecting elements *50A* of type "A" that has a particular electrical configuration are used in conjunction with a third interconnecting element *50D* of type "D" that has a different electrical configuration, to generate a selected electrical arrangement of the components on the three substrates *12*. Those skilled in the art will appreciate that other shaped interconnecting elements can be substituted with no loss of functionality. Also, the interconnecting element or plug does not necessarily have to be separate from the substrates. That is, integral plugs can be formed on, for example, opposing sides of the substrate and configured to closely fit with the connectors or sockets of adjacent substrates.

[0056] Because the interconnecting element *50A* in one embodiment is structurally symmetric but not necessarily electrically symmetric, the interconnecting element *50A* includes an orientation key *58* that indicates the electrical orientation. The interconnecting element *50A* also has an identifying mark "A" *60* indicating that it is a type "A" interconnecting element *50A*. Of course, other marks, a color coding scheme, or the like can also be used to identify the interconnecting element type. For example, a colored band (not shown) can be asymmetrically placed on the interconnecting element *50A*, in which the color correlates with the interconnecting element type and the asymmetric placement provides an orientation key.

[0057] With reference now to FIGURES *8A* through *11B*, four exemplary electrical configurations for interconnecting and terminating elements are described. The exemplary electrical configurations are described with reference to the electrical configuration of the substrate shown in FIGURES *3* and *5* in which each substrate *12* has two series-connected LED components *14a*, *14b* thereon. Furthermore, the interconnecting and terminating elements are configured using the conductor element *4* as the circuit ground.

[0058]

With particular reference now to FIGURES *8A* and *8B*, a series interconnection of

two such substrates *12* is described. The pre-selected series electrical configuration is shown in FIGURE *8A*. An interconnecting element *50S* electrically connects the conductor member *5* of a first substrate *12* with the conductor member *1* of a second substrate *12* to effectuate a series interconnect. Additionally, the ground conductor members *4* are connected to provide ground continuity across the substrates *12*. As shown in FIGURE *8B*, this corresponds to the illustrated interconnecting element *50S* in which the conductor member *5'* of the first port *52S* is electrically connected with the conductor member *1'* of the second port *54S* to effectuate the series interconnection, and the conductor member *4'* of the first port *52S* is electrically connected with the conductor member *4'* of the second port *54S* to maintain ground continuity.

[0059] With particular reference now to FIGURES *9A* and *9B*, a parallel interconnection of two substrates *12* is described. The pre-selected parallel electrical configuration is shown in FIGURE *9A*. An interconnecting element *50P* electrically connects the conductor member *1* of a first substrate *12* with the conductor member *1* of a second substrate *12*, and interconnects the conductor member *5* of the first substrate *12* with the conductor member *5* of the second substrate *12*, to effectuate the parallel interconnect. Additionally, the conductor member *4* of the first substrate *12* is interconnected with the conductor member *4* of the second substrate *12* to effectuate ground continuity across the substrates. As shown in FIGURE *9B*, this corresponds to the illustrated interconnecting element *50P* in which the conductor member *1'* of the first port *52P* is electrically connected with the conductor member *1'* of the second port *54P*, the conductor member *5'* of the first port *52P* is electrically connected with the conductor member *5'* of the second port *54P*, and the conductor member *4'* of the first port *52P* is electrically connected with the conductor member *4'* of the second port *54P*.

[0060] With particular reference now to FIGURES *10A* and *10B*, a terminating element *50T* is shown. The terminating element *50T* is appropriate, for example, for terminating one or more series- or parallel-interconnected substrates *12*. An electrical schematic showing the operation of the terminating element *50T* is shown in FIGURE *10A*. The terminating element *50T* electrically connects the conductor member *5* of the last substrate *12* to the circuit ground conductor member *4*. As shown in FIGURE *10B*, this

corresponds to the illustrated terminating element *50T* which has only a single port *52T* that has its conductor member *5'* electrically connected with the conductor member *4'* to effectuate the grounding of the conductor member *5'*.

[0061] With particular reference now to FIGURES *11A* and *11B*, a terminating element *50V* providing electrical power to a circuit assembly is described. The terminating element *50V* is appropriate, for example, for connecting one or more series- or parallel-interconnected substrates *12* to a source of electrical power. The electrical configuration is shown in FIGURE *11A*. The terminating element *50V* electrically connects the conductor member *1* to the positive terminal of an associated voltage source *V*, and also connects the ground conductor member *4* to the negative terminal of the associated voltage source *V*. As shown in FIGURE *11B*, this corresponds to the illustrated terminating element *50V* which has only a single port *54V*. The conductor member *1'* is electrically connected with the positive terminal of the associated voltage source *V*, while the conductor member *4'* is electrically connected to the negative terminal of the associated voltage source *V*. In one embodiment, the terminating element *50V* connects to the associated voltage source *V* through an electrical cable *64* that is disposed between the terminating element *50V* and the voltage source *V*. Of course, other electrical connecting and transmission elements can also be included, such as a jack (not shown) that detachably connects the cable *64* to the terminating element *50V*, and/or a jack (not shown) that detachably connects the cable *64* to the voltage supply *V*.

[0062] Other interconnecting and terminating elements are also contemplated. For example, a "null" interconnecting element (not shown) having no electrical interconnections therein can be provided. Such a "null" connecting element advantageously provides structural support to the modular mounting assembly without including corresponding electrical interconnections. It will also be recognized that the specific electrical configurations of the interconnecting elements depend upon both the selected electrical interconnection and on the electrical configuration of the substrate. The exemplary interconnecting and terminating elements of FIGURES *8A* through *11B* are appropriate for the substrate *12* illustrated in FIGURES *3* and *5*. Regardless of the electrical configuration, the mechanical configuration of the interconnecting elements is advantageously standardized to facilitate formation of

complex modular mounting structures such as the hexagonal structure *10* of FIGURE *1*.

[0063] In one aspect of the invention, standardized substrates are provided on which components, such as LED components, can be affixed. These substrates in combination with standardized interconnecting and terminating elements together cooperate to form selected modular interconnections of LED components. The interconnecting and terminating elements can advantageously include orientation key marks *58* and type indicators *60* to avoid misconnection. Although symbolic type indicators are shown in exemplary FIGURES *6* and *7*, other type indicators such as color coding schemes are also contemplated. The ports *52*, *54* also can be orientationally keyed (not shown) to further reduce the possibility improperly interconnecting the substrates comprising the modular mounting assembly.

[0064] With reference now to FIGURE *12*, an exemplary assembly of six LED components on three substrates *12* is shown. Power is supplied from the voltage source *V* via a terminating element *50V*. The three substrates *12* are interconnected using two series interconnecting elements *50S*. The series string is terminated by a terminating element *50T'*, which differs from the terminating element *50T* of FIGURES *10A* and *10B* in that an electrically unconnected second port is included to provide improved structural integrity. Although the extra port of terminating element *50T'* is shown as completely electrically unconnected, in another contemplated embodiment the ground terminals *4'* of the two ports are interconnected to provide additional ground continuity. In yet another contemplated embodiment (not shown) the terminating element *50T'* is replaced by a completely electrically unconnected interconnecting element that has no electrical interconnections and provides only structural support to the modular mounting, and a connector of type *50T* is connected to one of the unpaired ports of the last substrate *12* in the electrical series to provide the electrical termination.

[0065]

The illustrated modular configuration of FIGURE *12* can be converted to a configuration having the three substrates *12* in parallel with the two LED components *14a*, *14b* of each substrate *12* connected in series by simply replacing the two series interconnecting elements *50S* with corresponding parallel interconnecting elements

50P. The exemplary circuit shown in FIGURE *12* is rather simple. However, it will be appreciated that highly complex modular assemblies including dozens, hundreds, or even greater numbers of LED components having complex spatial arrangements, electrical interconnections, electrical sub-circuits, and the like can be created by appropriate selection and arrangement of a standardized set of substrates, interconnecting elements, and terminating elements. Another advantage of the present invention is that replacement of a failed LED component is greatly simplified, and requires only replacement of the substrate on which the failed LED component is disposed.

[0066] With reference now to FIGURES *13* and *14*, another embodiment of the modular mounting assembly is described. A substrate *12RGB* has six LED components arranged thereon: a first red LED component *14aR*, a first green LED component *14aG*, and a first blue LED component *14aB* arranged in a first receiving well *22a*; and a second red LED component *14bR*, a second green LED component *14bG*, and a second blue LED component *14bB* arranged in a second receiving well *22b*, as shown. The first and second LED component of each color is connected in series by PC board traces *40R*, *40G*, and *40G*. In order to accommodate the greater number of anode and cathode terminals in this tri-color substrate *12RGB*, connectors *16RGB* having seven conductor members each is used. As shown in the electrical schematic of FIGURE *14*, each of the three colors is independently addressable: conductor members *1* and *4* connect to the red LED series; conductor members *2* and *5* connect to the green LED series; and conductor members *3* and *6* connect to the blue LED series. The conductor member *7* serves as circuit ground in the substrate *12RGB*. For substrates having more complex interconnections such as those shown in FIGURES *13* and *14*, two-level or even more complex PC boards can be used to accommodate the larger number of traces involved.

[0067] It will be appreciated by those of ordinary skill in the art that the substrates comprising a modular mounting assembly need not have identical components arranged thereon, as long as the connectors are electrically and structurally compatible. Thus, for example, substrates having low intensity LED components (not shown) and substrates having high intensity LED components (not shown) can be intermixed in an array to form a dual-intensity lamp. Because the electrical

characteristics of LED components of different intensities often differ, and because it can be desirable to independently address the low intensity LED and the high intensity LED sub-arrays, different electrical conductor members can be advantageously used for the different LED intensities. Thus, for example, in a five-conductor connector, conductors *1* and *2* can be used for the low intensity LED interconnects, conductors *3* and *4* can be used for the high intensity LED interconnects, and conductor *5* can be used as the system ground. The substrates having only high intensity LED components advantageously have the conductor members *1* of the various connectors interconnected on the substrate, and similarly the conductor members *2* of the various connectors are advantageously interconnected, whereby electrical continuity for the low intensity sub-circuit is provided across the modular assembly. Similarly, the high intensity conductor members *3* and *4* of the connectors are advantageously interconnected, respectively, on the substrates having only low intensity LED components.

[0068] In another contemplated variation, blank substrates, e.g. substrates having no components thereon, can advantageously be used as spaceholders in the modular assembly. Once again, like electrical conductor members of the blank substrate connectors can be interconnected on the substrate to provide electrical continuity where necessary.

[0069] With reference now to FIGURES *15* and *16*, yet another embodiment of the invention is described, that is particularly suitable for interconnecting LED components on a flexible cable or other linear element. Such "LED strings" can be used as flexible linear light sources. As shown in FIGURE *15*, the embodiment includes a substrate *12C* that is essentially similar to the substrate *12* shown in FIGURES *3* and *5*, except that an additional vertically oriented connector *16C* is included on the substrate *12C*. As shown in FIGURE *16*, the connector *16C* advantageously connects to a power cable *70* to form the LED string. In order to maximize the modularity of the substrate *12C*, the substrate optionally retains the edge connectors *16*, so that the substrate *12C* can be used either in a planar array assembly such as the hexagonal assembly *10* of FIGURE *1*, or in a linear LED string assembly as shown in FIGURE *16*. Of course, the connectors *16* can also be omitted from the substrate *12C* to reduce manufacturing costs.

[0070] The invention has been described with reference to the preferred embodiments. Obviously, modifications and alterations will occur to others upon reading and understanding the preceding detailed description. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.